SL 1/987

Preprint from the 1987

BUREAU OF MINES MINERALS YEARBOOK

Slag—Iron and Steel

UNITED STATES DEPARTMENT OF THE INTERIOR

READEX FICHE best copy available

I 28.37/a:

UNITED STATES DEPARTMENT OF THE INTERIOR • Donald Paul Hodel, Secretary

BUREAU OF MINES • T S Ary, Director

This publication is a chapter from the current Bureau of Mines Minerals Yearbook, comprising *Volume I, Metals and Minerals; Volume II, Area Reports: Domestic; Volume III, Area Reports: International.* The separate volumes of the Yearbook are sold by the Superintendent of Documents, Washington, D.C. 20402.

Slag—Iron and Steel

By Judith F. Owens[1]

Iron and steel slag sales were essentially unchanged from those of 1986. A significant decrease in sales and use of steel slag was offset by an increase in sales of iron-blast-furnace slag. Air-cooled iron-blast-furnace slag continued to comprise the largest portion of total blast furnace slag sold or used.

The construction industry continued to be the major user of iron and steel slag products. Air-cooled iron-blast-furnace slag was used mainly for asphaltic concrete aggregate, concrete aggregate, fill, railroad ballast, and road base. The use of air-cooled slag as a road base decreased slightly from that of 1986. Sales and uses of granulated and expanded iron-blast-furnace slags increased significantly over that of 1986 and, were primarily used for fill, lightweight concrete aggregate, road base, soil conditioning, and the production of slag cement. Steel slag was typically used as road base and fill. The average unit values of both iron slag and steel slag remained essentially unchanged from those of 1986.

Domestic Data Coverage.—Sales, use, and transportation data for iron and steel slag are developed by the Bureau of Mines from a voluntary annual survey of U.S. processors. Of the 95 operations canvassed, 80 responded, representing 84% of the total sales or use data shown in table 1. Data for the nonrespondents were estimated based on prior year slag sales data. Of the 80 respondents, 4 reported their operations as idle and 3 reported their plants as closed.

DOMESTIC PRODUCTION

Domestic iron and steel slag production, which is not reported to the Bureau of Mines, apparently increased owing to a significant increase in U.S. iron and steel production. However, sales and consumption of iron and steel slag, as reported by processors, remained essentially unchanged from those of 1986, when combined. Steel slag consumption decreased significantly, but was offset by a slight increase in the sales and use of iron-blast-furnace slag. According to the U.S. Department of Commerce, private nonresidential and highway and bridge construction decreased 8% and 3%, respectively, and public construction increased 2%. Federal funding for highway construction was interrupted during 1987 as a result of an impasse in Congress over the renewal of spending authority under the Federal-aid-Highways Programs. In effect, this impasse most likely decreased slag consumption for road construction from October 1986 to April 1987.[2] Sales of slag products generally reflect demand from the construction industry.

Iron-blast-furnace slag sold or used increased slightly, totaling 15.8 million short tons valued at $96.1 million. Approximately two-thirds of this, in decreasing order, was produced in Indiana, Pennsylvania, Ohio, and Michigan.

Table 1.—Iron and steel slags sold or used[1] in the United States

(Thousand short tons and thousand dollars)

Year	Iron-blast-furnace slag								Steel slag		Total slag[2]	
	Air-cooled		Granulated		Expanded		Total iron slag[2]					
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1963	12,280	50,989	(3)	(3)	1,175	13,726	13,554	64,735	4,832	14,546	18,386	79,280
1964	15,225	66,289	(3)	(3)	1,452	19,142	16,776	85,432	5,297	17,327	22,063	102,756
1965	13,363	62,588	(3)	(3)	1,742	24,290	15,106	86,878	5,972	17,472	21,078	104,351
1966	13,501	58,899	(3)	(3)	1,879	33,851	15,380	92,750	5,689	17,883	21,068	110,633
1967	13,448	61,092	(3)	(3)	2,289	35,093	15,287	96,096	4,935	15,354	20,772	111,449

[1]Value based on selling price at plant.
[2]Data may not add to totals shown because of independent rounding.
[3]Included with "Expanded" to avoid disclosing company proprietary data.

Of all the iron and steel slag products sold, 86% traveled by truck with an average marketing range of 32 miles; 7% traveled by waterway with an average range of 559 miles; and 7% traveled by rail with an average range of 156 miles. The remaining 1% was used at the plant where it was processed.

CONSUMPTION AND USES

Iron and steel slags were consumed mainly by the construction industry as substitutes for natural aggregates and other construction materials. Historically, iron and steel slags have been used in place of other materials because of their lower costs, superior performance for many applications, or shortages of natural aggregates.

Practically all of the iron-blast-furnace slag products are eventually utilized. Of the air-cooled iron-blast-furnace slag sold or used in 1987, 53% was used as road base, 13% as concrete aggregate, 10% as fill, 8% as asphaltic concrete aggregate, and 5% as railroad ballast. The remaining 11% was used in concrete products, glass manufacture, mineral wool, soil conditioning, sewage treatment, and other miscellaneous uses. Expanded blast furnace slag was mainly used as a lightweight concrete aggregate. Granulated blast furnace slag was mainly utilized in cement manufacture. The largest growth area for iron slag appears to be in the replacement of cement in concrete construction and in fill.

Based on raw steel production, an estimated 3.1 million tons of steel slag was recycled to blast furnaces in 1987. However, the bulk of the steel slag produced was used in aggregate applications. Steel slag processed and sold primarily as road base comprised 44%; as fill, 25%; as asphaltic concrete aggregate, 13%; and as railroad ballast, 8%. The remaining 15% was used for ice control, soil conditioning, and miscellaneous uses. The major growth areas for steel slag usage would appear to be as fill and road base.

PRICES

The average price, f.o.b. plant, for all iron-blast-furnace slag sold remained essentially unchanged at $6.07 per ton. The price of air-cooled iron slag increased 4% over that of 1986 to $4.54 per ton. The average price of granulated iron slag showed a significant decrease from that of 1986, reflecting a significant increase of lower priced granulated slag entering the marketplace. Expanded slag price information was withheld to avoid disclosing company proprietary data. The unit value of steel slag remained stable.

FOREIGN TRADE

U.S. foreign trade data for iron and other steel slag cannot be determined because slag is classified in categories with other materials and cannot be separated. U.S. exports of slag are classified under the headings "Metal Bearing Ores and Metal Bearing Materials" or "Waste and Scrap Not Specifically Provided For."

Basic slag, a byproduct of basic steelmaking processes, is imported for use as a fertilizer because of its high lime and phosphorus content. Statistics developed by the U.S. Department of Commerce, Bureau of the Census, indicated that 82,394 tons of basic slag valued at $786,000 was imported from Canada, and 38,524 tons valued at $310,058 was imported from Japan. Basic slag was also imported from the Federal Republic of Germany, 11,589 tons valued at $89,148, followed by Mexico with 895 tons valued at $6,716, and the United Kingdom with 813 tons valued at $5,818.

WORLD REVIEW

Estimated world production of iron-blast-furnace slag and steel slag was 130 million tons and 58 million tons, respectively. These estimates are based on iron and steel production estimates for 1987. Reported production of iron and steel slag by country is incomplete owing to late reporting, incompleteness of data, and lack of reporting by some countries. Some countries do not report slag production because slag is thought of as a waste product rather than as a resource.

Production estimates for major world producers of iron-blast-furnace slag and steel slag, respectively, are as follows: European Economic Community, 21 million tons and 10 million tons; Japan, 27 million tons and 14 million tons; and U.S.S.R., 27.8 million tons and 8.8 million tons. These production estimates, based on estimated production of iron and steel, have remained essentially unchanged from those of 1986.

TECHNOLOGY

Pretoria Portland Cement Ltd.'s Newcastle portland blast furnace cement plant in the Republic of South Africa made use of new technology in the processing of granulated iron-blast-furnace slag. For the first time in the country, tubular conveyors were used that operated at steeper angles than did standard conveyors, and they could turn corners horizontally. Another first was the use of a fluidized bed for drying of the slag. Owing to the efficient design of the facility, it occupies a smaller area than do most slag processors and has encountered fewer problems with spillage. This facility, which produces a finished product called slagment, offers the Republic of South Africa's construction industry a new source for concrete products and a new market for blast furnace slag processors.[3]

The American Concrete Institute reported that, owing to rising costs of portland cement, recent attention has focused on the use of ground, granulated blast furnace slag as a separate constituent in concrete. Advantages to the cement industry include reduced costs, improved workability, and increased ultimate compressive and flexural strength. Advantages to the slag industry would be a higher valued product per ton, greatly surpassing the value of other end uses.[4]

A process for stabilizing steelmaking slag was granted a U.S. patent in 1987. In this process, a boron-containing mineral such as borax or kernite is added to the slag prior to cooling. This prevents the slag from powdering during the cooling stage. This would be advantageous to the steel slag industry because the slag would be easier to handle and the process would produce a homogenous product.[5]

Researchers in Japan have discovered that certain types of iron-blast-furnace slags are an effective deterrent in the liberation of phosphate from sediments in shallow or coastal waters. It was determined that the most effective type of iron slag was soft granulated iron slag, which suppressed the phosphate liberation by as much as 98.8% when mixed with or laid upon the sediments. This discovery may be important to marine biology in helping to control eutrophication or the oversaturation of water with nutrients that can lead to oxygen deficiencies in closed water areas.[6]

---

[1]Physical scientist, Branch of Ferrous Metals.

[2]U.S. Department of Commerce. Construction Review. V. 33, No. 6, Nov.-Dec. 1987, pp. 2, 11.

[3]Venter, P. W. Construction of a New Slag Processing Factory at Newcastle. South Afr. Mech. Eng., v. 37, May 1987, pp. 207-211.

[4]ACI Committee 226. Ground Granulated Blast-Furnace Slag as a Cementitious Constituent in Concrete. ACI Mater. J., v. 84, No. 4, Jul.-Aug. 1987, pp. 327-342.

[5]Ishizaka, K., F. Sudo, A. Seki, and Y. Aso. Method of Stabilizing a Steel Making Slag. U.S. Pat. 4,655,831, Apr. 7, 1987.

[6]Yamada, H., K. Mitsu, S. Kazuo, and H. Masakazu. Suppression of Phosphate Liberation From Sediment Using Iron Slag. J. Int. Assoc. on Water Pollu. Res. & Control, v. 21, No. 3, Mar. 1987, pp. 225-233.

Table 2.—Iron-blast-furnace slags sold or used[1] in the United States, by region and State

(Thousand short tons and thousand dollars)

Region and State	1986				1987			
	Air-cooled, screened and uncrushed		Total, all types		Air-cooled, screened and uncrushed		Total, all types	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
North Central:								
Illinois, Indiana, Michigan	5,079	16,235	W	W	5,922	17,346	W	W
Ohio	2,202	12,744	W	W	2,252	14,293	W	W
Total	7,281	28,979	7,900	34,229	7,604	31,639	8,273	36,229
Middle Atlantic:								
Maryland, New York, West Virginia	1,227	5,774	W	W	W	W	W	W
Pennsylvania	2,460	13,805	2,827	20,235	2,109	12,851	W	W
Total	3,687	19,579	W	W	W	W	5,174	30,000
West: Colorado, Texas, Utah	1,198	4,645	1,198	4,645	W	W	W	W
South: Alabama and Kentucky	612	3,963	612	3,963	W	W	W	W
Pacific: California	730	2,236	730	2,236	808	2,776	808	2,776
Grand total[2]	13,501	58,899	15,290	92,750	13,449	81,094	15,027	96,000

W Withheld to avoid disclosing company proprietary data; included in "Total" and "Grand total."

[1]Value based on selling price at plant.

[2]Data may not add to totals shown because of independent rounding.

Table 3.--Locations and processing methods of iron slag and sources of steel slag[1] in 1987

State, city, and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Air-cooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
Alabama:							
Alabama City:							
Vulcan Materials Co	1	--	--	1	--	1	--
Fairfield:							
Vulcan Materials Co	1	--	--	1	--	1	--
Total	2	--	--	2	--	2	--
Arkansas: Fort Smith:							
International Mill Service Co	--	--	--	1	--	--	1
California: Fontana:							
Heckett Co	1	--	--	--	--	--	--
Colorado: Pueblo:							
Fountain Sand and Gravel Co	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Total	1	--	--	1	--	1	--
Delaware: Claymont:							
International Mill Service Co	--	--	--	1	--	1	--
Florida: Tampa:							
International Mill Service Co	--	--	--	1	--	--	1
Georgia:							
Atlanta:							
International Mill Service Co	--	--	--	1	--	--	1
Cartersville:							
International Mill Service Co	--	--	--	1	--	--	1
Total	--	--	--	2	--	--	2
Illinois:							
Alton:							
International Mill Service Co	--	--	--	1	--	--	1
Chicago:							
Heckett Co	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Granite City:							
International Mill Service Co	--	--	--	1	--	1	--
St. Louis Slag Products Co. Inc	1	--	--	--	--	--	--
Total	2	--	--	3	--	2	1
Indiana:							
Burns Harbor:							
The Levy Co. Inc	1	1	--	1	--	1	--
East Chicago:							
Heckett Co	--	--	--	1	--	1	--
The Levy Co. Inc	1	--	--	--	--	--	--
Gary:							
International Mill Service Co	--	--	--	1	--	1	1
Total	2	1	--	3	--	3	1
Iowa: Keokuk:							
International Mill Service Co	--	--	--	1	--	--	1
Kentucky: Ashland							
Heckett Co	1	--	--	--	--	--	--
Louisiana: LaPlace:							
International Mill Service Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 2.—Locations and processing methods of iron slag and sources of steel slag[1] in 1967—Continued

State, city, and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Air-cooled	Air-granulated	Granulated		Open hearth	Basic oxygen process	Electric
Maryland:							
Baltimore:							
Maryland Slag Co	1	--	--	--	--	--	--
Sparrows Point:							
Blue Circle Atlantic	--	--	1	--	--	--	--
C. J. Langenfelder & Sons Inc	--	--	--	1	1	1	--
Total	1	--	1	1	1	1	--
Michigan:							
Detroit:							
Edward C. Levy Co	1	1	--	1	--	1	1
Monroe:							
International Mill Service Co	--	--	--	1	--	--	1
Total	1	1	--	2	--	1	2
Minnesota: Newport:							
International Mill Service Co	--	--	--	1	--	--	1
Mississippi: Jackson:							
Hackett Co	--	--	--	1	--	--	1
Missouri: Kansas City:							
International Mill Service Co	--	--	--	1	--	--	1
New Jersey:							
Perth Amboy:							
International Mill Service Co	--	--	--	1	--	--	1
Riverton:							
International Mill Service Co	--	--	--	1	--	--	1
Total	--	--	--	2	--	--	2
New York: Buffalo:							
Buffalo Crushed Stone Corp	1	--	--	--	--	--	--
North Carolina: Charlotte:							
Hackett Co	--	--	--	1	--	--	1
Ohio:							
Canton:							
Hackett Co	--	--	--	1	--	--	1
Cleveland:							
Standard Slag Co	1	--	--	--	--	--	--
Do	1	--	--	--	--	--	--
Stein Inc	--	--	--	1	--	1	1
Hamilton:							
American Materials Corp	1	--	--	--	--	--	--
Lorain:							
Fritz Enterprises Inc	1	--	--	--	--	--	--
Stein Inc	--	--	--	1	--	1	--
Lordstown:							
Standard Slag Co	--	--	1	--	--	--	--
Mansfield:							
Hackett Co	--	--	--	1	--	--	1
Marion:							
International Mill Service Co	--	--	--	1	--	--	1
Middletown:							
American Materials Corp	1	--	--	--	--	--	--
International Mill Service Co	--	--	--	1	--	1	--
Mingo Junction:							
International Mill Service Co	--	--	--	1	--	1	--
Standard Slag Co	1	--	--	--	--	--	--
Warren:							
Hackett Co	--	--	--	1	--	1	1
Standard Slag Co	1	--	--	--	--	--	--
Total	7	--	1	8	--	5	5
Oklahoma: Sand Springs:							
International Mill Service Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987 —Continued

State, city, and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Air-cooled	Expanded	Granulated		Open hearth	Basic oxygen process	Electric
Pennsylvania:							
Bala-Cynwyd:							
Warner Co	1	1	--	--	--	--	--
Beaver Falls:							
International Mill Service Co	--	--	--	1	--	--	1
Belle Vernon:							
Duquesne Slag Products Co	1	--	--	--	--	--	--
Bethlehem:							
Sheridan Slag Corp	--	1	--	--	--	--	--
Burgettstown:							
Duquesne Slag Products Co	--	--	1	--	--	--	--
Butler:							
Heckett Co	--	--	--	1	--	--	1
Coatesville:							
International Mill Service Co	--	--	--	1	--	--	1
Johnstown:							
Heckett Co	--	--	--	1	--	--	1
Lebanon:							
Sheridan Slag Corp	1	--	--	--	--	--	--
Midland:							
International Mill Service Co	--	--	--	1	--	--	1
Monessen:							
International Mill Service Co	--	--	--	1	--	1	--
Morrisville:							
Heckett Co	--	--	--	1	1	--	--
Patton:							
International Mill Service Co	--	--	--	1	--	1	--
Penn Hills:							
Gascola Slag Co	--	--	--	1	1	--	--
Phoenixville:							
International Mill Service Co	--	--	--	1	--	--	1
Riddlesburg:							
New Enterprise Stone & Lime Co. Inc	1	--	--	--	--	--	--
Steelton:							
Hempt Bros. Inc	--	--	--	1	--	--	1
West Aliquippa:							
Duquesne Slag Products Co	1	--	--	1	--	1	--
West Mifflin:							
Duquesne Slag Products Co	1	--	--	--	--	--	--
Do	1	--	--	1	--	1	--
Wheatland:							
Dunbar Slag Co. Inc	1	--	--	1	1	1	--
Total	8	2	1	14	3	5	7
South Carolina: Georgetown:							
Heckett Co	--	--	--	1	--	--	1

See footnote at end of table.

Table 3.—Locations and processing methods of iron slag and sources of steel slag[1] in 1987—Continued

State, city, and company	Processing method of iron slag			Steel slag	Sources of steel slag		
	Air-cooled	Expanded	Granulated		Open hearth	Basic-oxygen process	Electric
Texas:							
Beaumont:							
International Mill Service Co.	--	--	--	1	--	--	1
El Paso:							
International Mill Service Co.	--	--	--	1	--	--	1
Lone Star:							
Gifford-Hill & Co. Inc	1	--	--	--	--	--	--
Longview:							
International Mill Service Co.	--	--	--	1	--	--	1
Midlothian:							
International Mill Service Co.	--	--	--	1	--	--	1
Seguin:							
International Mill Service Co.	--	--	--	1	--	--	1
Total	1	--	--	5	--	--	5
Utah:							
Plymouth:							
International Mill Service Co.	--	--	--	1	--	--	1
Provo:							
Heckett Co.	1	--	--	1	1	--	--
Total	1	--	--	2	1	--	1
Washington: Seattle:							
Heckett Co.	--	--	--	1	--	--	1
West Virginia: Weirton:							
International Mill Service Co	--	--	--	1	--	1	--
Standard Slag Co.	1	--	--	--	--	--	--
Total	1	--	--	1	--	1	--
Grand total	30	4	3	58	5	22	37

[1]Number indicates the existence of an active plant shown by processing method or furnace source; previous years showed the number of active processing lines for some plants.

Table 4.—Shipments of iron and steel slag in the United States in 1987, by method of transportation

Method of transportation	Quantity (thousand short tons)
Truck	17,907
Waterway	1,419
Rail	1,227
Not transported (used at plant site)	219
Total	20,772

Table 5.—Air-cooled iron-blast-furnace slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986		1987	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	977	5,089	1,094	6,351
Concrete aggregate	1,753	8,799	1,717	8,758
Concrete products	513	2,474	317	1,930
Fill	779	3,237	1,358	4,058
Glass manufacture	107	W	W	W
Mineral wool	519	2,862	488	2,614
Railroad ballast	875	3,826	675	3,141
Road base	7,483	28,165	7,187	20,050
Roofing, built-up and shingles	74	560	82	744
Sewage treatment	W	W	W	W
Soil conditioning	W	W	W	W
Other[2]	452	[3]3,767	560	[3]3,446
Total[4]	13,501	58,899	13,448	61,092

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Value based on selling price at plant.
[2]Includes ice control, miscellaneous uses, and data indicated by symbol W.
[3]Includes glass manufacture.
[4]Data may not add to totals shown because of independent rounding.

Table 6.—Granulated and expanded iron-blast-furnace slags sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Uses	1986				1987			
	Granulated		Expanded		Granulated		Expanded	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Cement manufacture	(2)	(2)	W	W	(2)	(2)	W	W
Concrete products	--	--	W	W	--	--	--	--
Fill	(2)	(2)	W	W	(2)	(2)	W	W
Lightweight concrete aggregate	--	--	W	W	--	--	W	W
Road base	(2)	(2)	W	W	(2)	(2)	W	W
Soil conditioning	(2)	(2)	W	W	(2)	(2)	W	W
Other[3]	(2)	(2)	1,879	33,851	(2)	(2)	2,389	35,003
Total	(2)	(2)	1,879	33,851	(2)	(2)	2,389	35,003

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Value based on selling price at plant.
[2]Included with "Expanded" to avoid disclosing company proprietary data.
[3]Includes miscellaneous uses and data indicated by symbol W.

Table 7.—Steel slag sold or used[1] in the United States, by use

(Thousand short tons and thousand dollars)

Use	1986		1987	
	Quantity	Value	Quantity	Value
Asphaltic concrete aggregate	632	2,613	634	2,810
Fill	1,318	5,961	1,215	5,410
Railroad ballast	W	W	164	518
Road base	2,549	7,879	2,179	6,546
Other[2]	1,190	3,531	753	2,075
Total[3]	5,689	17,883	4,935	15,354

W Withheld to avoid disclosing company proprietary data; included with "Other."
[1]Excludes tonnage returned to furnace for charge material. Value based on selling price at plant.
[2]Includes ice control, soil conditioning, miscellaneous uses, and data indicated by symbol W.
[3]Data may not add to totals shown because of independent rounding.

Table 8.—Average value at the plant for iron and steel slags sold or used in the United States

(Dollars per short ton)

Year	Iron-blast-furnace slag				Steel slag	Total slag
	Air-cooled	Granulated	Expanded	Total iron slag		
1983	4.12	W	9.67	4.78	3.01	4.31
1984	4.33	W	11.49	5.09	3.25	4.66
1985	4.62	W	11.00	5.75	2.93	4.95
1986	4.56	21.26	12.57	6.03	3.14	5.25
1987	4.54	11.14	W	6.07	3.11	5.26

W Withheld to avoid disclosing company proprietary data.

Table 9.—Average selling price and range of selling prices at the plant for iron and steel slags in the United States in 1987, by use

(Dollars per short ton)

Use	Iron-blast-furnace slag						Steel slag	
	Air-cooled		Granulated		Expanded			
	Average	Range	Average	Range	Average	Range	Average	Range
Asphaltic concrete aggregate	5.81	2.44- 9.33	--	--	--	--	4.51	2.30-5.29
Cement manufacture	--	--	W	W	--	--	--	--
Concrete aggregate	5.10	2.55- 9.09	W	W	--	--	--	--
Concrete products	6.10	1.84- 9.09	--	--	--	--	2.81	1.00-6.75
Fill	2.99	1.50- 7.12	W	W	--	--	--	--
Glass manufacture	W	W	--	--	--	--	--	--
Lightweight concrete aggregate	--	--	--	--	W	W	--	--
Mineral wool	5.26	3.43-10.54	--	--	--	--	--	--
Railroad ballast	4.66	3.71- 8.00	--	--	--	--	3.13	2.65-3.75
Road base	4.20	2.17- 9.09	W	W	--	--	3.00	1.69-5.80
Roofing, built-up and shingles	9.03	5.16-11.55	--	--	--	--	--	--
Sewage treatment	W	W	--	--	--	--	--	--
Soil conditioning	W	W	W	W	--	--	2.69	2.19-4.08
Other	4.25	3.37- 6.30	11.14	1.62-34.29	W	W		

W Withheld to avoid disclosing company proprietary data; included with "Other."

☆ U.S. GOVERNMENT PRINTING OFFICE: 1988— 242- 377/ 80029